The results of this investigation are being used to support further development of the CDTI and its eventual installation in many more aircraft. Additionally, evaluation of this prototype is contributing to future CDTI designs and their applications toward free-flight for all aircraft. This has significant implications for future aviation capacity and safety enhancements, and supports the Aerospace Technologies Enterprise goal of tripling throughput while maintaining safety in the National Airspace System.

Point of Contact: R. Ashford
(650) 604-0914
rashford@mail.arc.nasa.gov

Rotorcraft Uninhabited Aerial Vehicle (RUAV) System Identification, Modeling, and Flight Control System Development

Mark B. Tischler, Luigi S. Cicolani, Jason D. Colbourne, Chad R. Frost

A new challenge to industry and the government alike is the trend toward highly compressed schedules for rotorcraft uninhabited aerial vehicle (RUAV) development and system fielding. Current RUAV proposals and development programs are on 6- to 9-month schedules, in contrast to the 6- to 10-year schedules common to most recent piloted rotorcraft systems. This year, the Army/NASA Rotorcraft Division launched a new initiative: COntrol and Simulation Technologies for Autonomous Rotorcraft (COSTAR) which seeks to develop key enabling technologies for the control and simulation of RUAVs.

The COSTAR initiative refines technologies originally developed for manned rotorcraft for application to the RUAV problem, and seeks to increase technology integration sufficiently to realize the desired reduction in design cycle time. Key elements of COSTAR include accurate flight-mechanics modeling using system identification (CIFER®), control system design optimization for multiple objectives (CONDUIT), and real-time workstation-based simulation (RIPTIDE). COSTAR technologies are central to three ongoing cooperative projects, in which university and industry RUAV developers have teamed with the Army/NASA Rotorcraft Division's Flight Control Technology Group.

In one such cooperative activity, Army/NASA personnel worked under direct contract to Northrop Grumman, supporting development of the U.S. Navy's Vertical Takeoff UAV (VTUAV) (figure 1). Ames personnel participated in flight testing, followed by extensive system identification of the aircraft dynamic models (using CIFER®), and flight control analysis/optimization (using CONDUIT). Ames was also responsible for developing the detailed flight control preliminary design, including the determination of a comprehensive set of "Aeronautical Design Standard-33 (ADS-33) like" design requirements for use in CONDUIT. This close working relationship resulted in a successful autonomous flight of the demonstrator aircraft. The Flight Control Technology Group is currently under contract to Northrop Grumman to support system identification of forward flight models, and flight control law optimization for the full flight envelope.

Another joint venture involves model identification, control system design, and flight testing of a fully instrumented model-scale unmanned helicopter (a Yamaha R-50 with 10-foot-diameter rotor). In conjunction with Carnegie-Mellon University, the CIFER® system identification techniques developed for full-size helicopters were applied to the R-50. An accurate, high-bandwidth, linear state-space model was derived for the hover condition. A conclusion of this study was that small helicopters seem to be particularly well suited to identification, in part because of the dominance of the rotor in their dynamics. This is illustrated by the exceptionally clean frequency-sweep time responses shown in figure 2. The R-50 was shown to be dynamically similar to a scaled UH-1H, although the R-50 is proportionally heavier. Preliminary control system designs have been studied using CONDUIT, and evaluated using the RIPTIDE simulation environment for remotely piloted operations.

Army/NASA personnel and technology have also been instrumental in Kaman Aerospace's development of the Broad-area Unmanned Responsive Resupply Operations (BURRO) aircraft for the U.S. Marine Corps. The BURRO program adapts the existing K-MAX piloted external-lift helicopter for

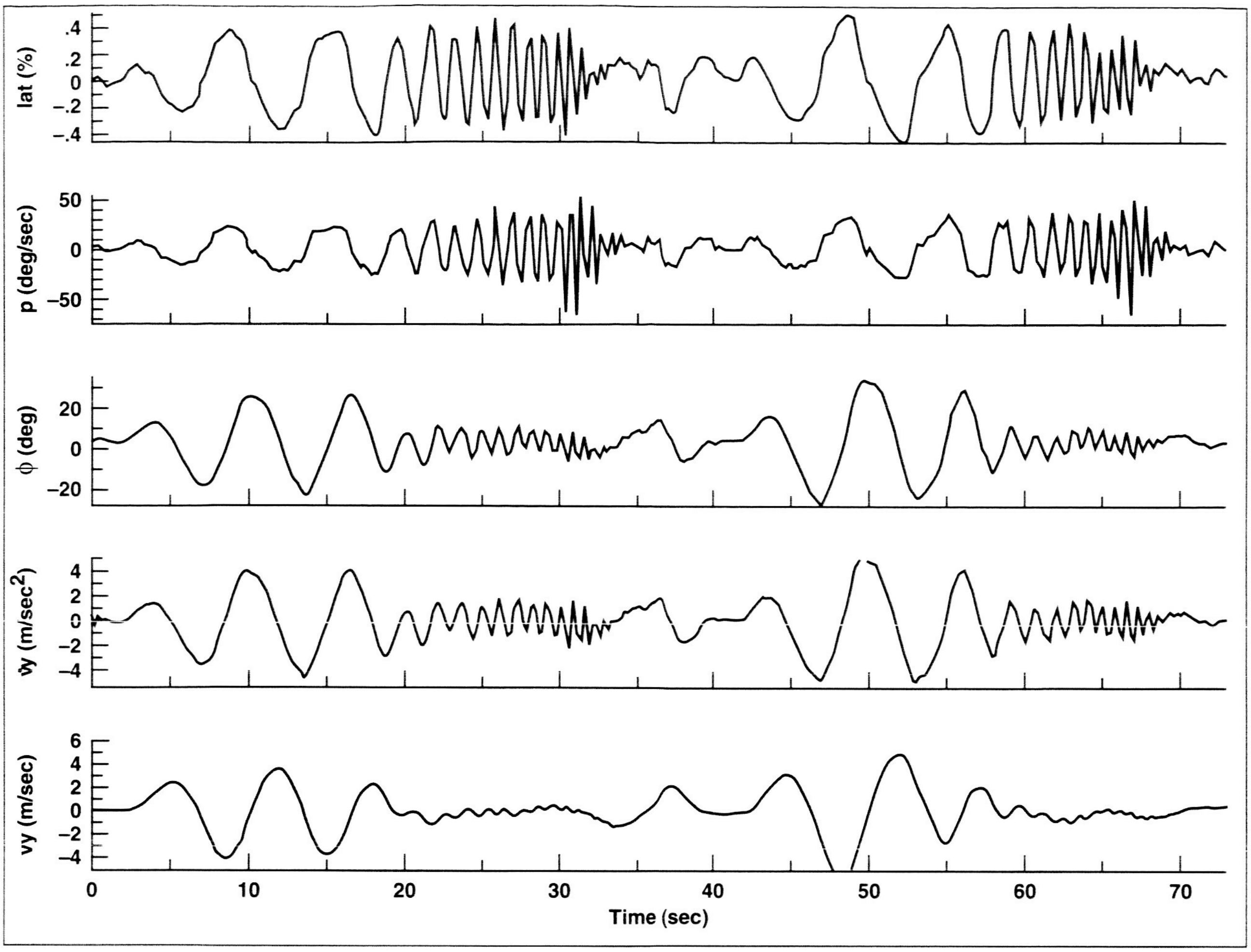

Fig. 1. Frequency sweeps collected for R-50 identification.

remotely piloted flight and autonomous way-point navigation. CIFER® was used to identify linear math models for unloaded and loaded flight at hover and at 50 and 80 knots; this is the first time that system identification has been used to extract a coupled aircraft-plus-slung load model. The resulting linear models were used to design and tune a flight control system in the CONDUIT environment—19 design parameters were tuned to meet 41 handling-quality and performance specifications, which were based on the ADS-33 manned rotorcraft requirements. This work led to a successful flight demonstration of the K-MAX BURRO UAV for the Marine Corps. Follow-on work will expand the range and capabilities of the demonstrator aircraft.

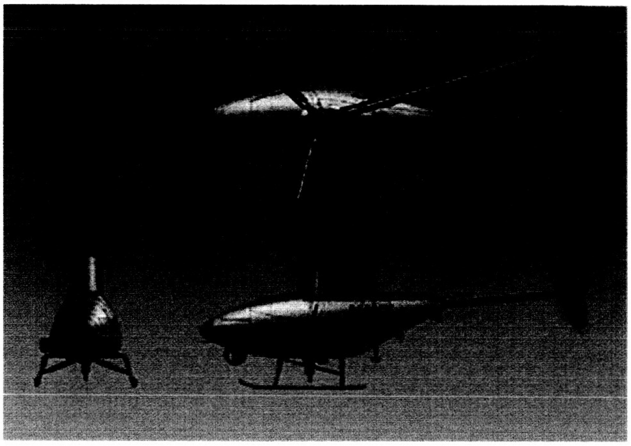

Fig. 2. VTUAV aircraft.

Point of Contact: M. B. Tischler
(650) 604-5563
mtischler@mail.arc.nasa.gov